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AN INVESTIGATION OF THE INFLUENCE
OF ADVANCED AIRCRAFT DIAGNOSTICS ON
THE TECHNOLOGICAL SOPHISTICATION OF
MAINTENANCE PERSONNEL

THESIS

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THESIS

Presented to the Faculty of the School of Systems and

Logistics of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the

Requirements for the Degree of

Master of Science in Logistics Management

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Preface

The purpose of this research was to determine the impact of automation and expert systems on the technical ability of Air Force personnel. The Air Force is at the forefront in adopting these technologies for troubleshooting aircraft problems. This study focuses on the impact that technology has had on the worker in the past and draws conclusions about the projected capabilities of units using advanced diagnostics.

This study could not have been completed without outside help. We wish to thank our faculty advisors, Lieutenant Colonel Phillip E. Miller and Major John Stibravy. From the very inception of this project, their help and advice has kept us on track. Captain Robert E. Dulong from the Air Combat Command staff also helped by providing background information about current trends and problems being encountered with expert systems in the field. Our thanks also go out to all those who assisted us with the library search that was required in order to complete this project. Finally, we owe our greatest gratitude to our families, Sharon Collins and Sharon and Jake Knaub, respectively, who sacrificed our presence at many activities while this study was completed. Their undying support helped make this effort a success.

Christopher R. Collins
Clete W. Knaub

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Abstract

The purpose of this research was to determine what effect automated diagnostic systems will have on the maintenance worker's technological capabilities. Four investigative questions guided the project: 1. What effect has automation of skilled jobs had on workers in the civilian community?; 2. What technological and psychological traits have led to success in past military conflicts?; 3. What types of technological and psychological traits will technicians have who are heavily dependent on diagnostic systems? (For example, to what degree will maintenance technicians be able to improvise when deployed to a combat area?); and, 4. What lessons can Air Force maintenance managers learn from the civilian community and past military experience?

The study was conducted by performing a literature review of material from both military operational data and civilian data regarding automation and expert systems. Answers to the research questions were inferred from the collective resources studied.

The study found that automation has impacted workers' technological capabilities in the past. Additionally, traits of successful technological workers were identified. Guidance helpful to managers and engineers implementing advanced diagnostics is also provided within the research.

AN INVESTIGATION OF THE INFLUENCE OF ADVANCED AIRCRAFT DIAGNOSTICS ON THE TECHNOLOGICAL SOPHISTICATION OF MAINTENANCE PERSONNEL

I. Introduction

General Issue

The dissolution of the Soviet Union and the fall of the Iron Curtain, unimaginable events just a few years ago, are realities today. The rapid movement toward peace at the superpower level is causing great changes in politics, the military, and economics. The push for a "peace dividend" by Congress and the President has compelled the Department of Defense and the Air Force to consider ways to reduce operating costs and still maintain an acceptable level of deterrent force.

In this period of dramatically decreasing defense budgets, Air Force officials must seek ways to reduce the cost of maintaining aircraft despite the increasing complexity of aircraft technology. Soon, the aircraft maintenance officer will be faced with the task of providing safe, mission-capable aircraft with smaller budgets and a reduced work force.

One solution being developed is automated aircraft diagnostic systems that incorporate expert systems technology. The promise of expert systems can be especially

advantageous for the Air Force maintenance officer contemplating the future. Projected trends in future military avionics suggest that advanced maintenance techniques will be required (10:73). Automated diagnostics will be at the forefront of these techniques. Several future and projected systems include the B-1B Central Integrated Test System (CITS) Expert Parameter System (CEPs) (13:500), the Self-Repairing Flight Control System (18:504), and even a personal computer-based Expert Diagnostic Tool (10:73). These systems will not only reduce the amount of training that the technician will receive, but will also influence how he accomplishes his job (56:1352).

Many studies have been done detailing the present and future capabilities of these diagnostic systems in terms of equipment technology. However, little has been done to examine what consequences these systems will have on the technological capabilities possessed by Air Force maintenance technicians. Strategic Air Command's office of logistics has expressed interest in this topic and is the sponsor of this study.

Problem Statement

Air Force managers have not determined what effect automated diagnostic systems will have on the maintenance worker's technological capabilities.

Research Objectives

The purpose of this research is to estimate if automated aircraft diagnostic systems will have a detrimental effect in developing and maintaining technological skills in USAF personnel.

Investigative Questions

To understand what effect these diagnostic systems will have on future technician's capabilities, the following questions must be addressed:

1. What effect has automation of skilled jobs had on workers in the civilian community?
2. What technological and psychological traits have led to success in past military conflicts?
3. What types of technological and psychological traits will technicians have who are heavily dependent on diagnostic systems? (For example, to what degree will maintenance technicians be able to improvise when deployed to a combat area?)
4. What lessons can Air Force maintenance managers learn from the civilian community and past military experience?

Scope and Limitations

This research will deal only with aircraft maintenance. Other areas of maintenance will not be addressed. This thesis will draw on both military and civilian experience in implementing automated systems. Finally, this research is exploratory in nature. The intent of this study is to

determine if automated diagnostic systems will have an adverse effect on the maintenance skills of USAF personnel. Recommendations will then be made based on these findings.

Target Audience

This thesis is directed toward the Air Force engineer and program manager who will have responsibility for developing and implementing automated diagnostic systems into aircraft in the future. This thesis' literature review will show that the Air Force has given very little forethought to what impact these diagnostic systems will have on the humans who must interface with them. The literature review will also show that careful, deliberate planning must precede the implementation of the automated systems if workers are to integrate successfully with them.

This thesis will supply the program manager and engineer with several proposals that can be taken in the early stages of development of an automated system that will increase the probability of successfully integrating the system with the people who will operate it. These recommendations are based on the literature reviewed describing past successes and failures in implementing automated systems in the civilian industry. These recommendations are also based on the authors' combined years of flightline experience.

Automated diagnostic systems will prove themselves to be very valuable tools in the future. However, they are a

double-edged sword, and they must be carefully designed for the maintenance technicians who will use them. It is to this purpose that this thesis is dedicated.

Overview of the Thesis

Chapter I has provided a basic overview of the general issues, specific problems, research objectives, and scope of this study. Chapter II will discuss the methodology used to solve the research questions and will assess the results of the data generated. The Chapter III literature review will begin with background information on Air Force plans for including automated systems and expert systems in aircraft. The literature review will discuss the effects automation has had on skilled workers in the civilian community and identify what technological traits have been essential to securing victory in past military conflicts.

Chapter IV will analyze the results of the literature review and gives individual answers to the research questions listed in Chapter I. Chapter V will summarize the results of the literature review and analysis. Chapter V will also make recommendations about future study in this area and will give suggestions to Air Force planners as they prepare to implement automated diagnostic systems Air Force-wide.

II. Methodology

Introduction

This chapter outlines the methodology used to solve the research questions posed in Chapter I. The purpose of this research is to determine if advanced aircraft diagnostic systems will have an unfavorable influence on the degree of technological sophistication possessed by Air Force technicians.

Data Gathering

Since the impact of automation on the work force is not a new phenomenon, data is available detailing how the technician/worker is influenced by the addition of new technologies. Inferences about the impact of automated aircraft diagnostics systems on the maintenance technician are based on the effects automation has had on the general work force in the past. The investigative questions were answered by conducting an extensive literature review. Commercial and military literature dealing with automation and technology have been used to suggest hypotheses for future study and to answer the investigative questions.

Specifically, Question One (What effect has automation of skilled jobs had on workers in the civilian community?) was dealt with by reviewing civilian research literature and determining what the impact was on skilled workers after their jobs had been partly automated. Question Two (What

technological traits have led to success in past military conflicts?) was addressed by reviewing military operations literature. Question Three (What types of technological traits will technicians have who are heavily dependent on diagnostic systems?) was addressed by reviewing civilian and military studies on the effects of automation of jobs. Question Four (What lessons can Air Force maintenance managers learn from the civilian community and past military experience?) builds on the results of Questions One, Two, and Three and is addressed in Chapter IV.

The library search used to gather information was accomplished at Wright State University (WSU), the Air Force Institute of Technology (AFIT) Academic Library, the Aircraft Systems Division (ASD) Technical Library at Wright-Patterson Air Force Base, and the Wright-Patterson Air Force Base Medical Center Library. Additionally, a Defense Technical Information Center (DTIC) literature search was completed. Both cost effectiveness and proven results were major factors in choosing AFIT ,WSU, ASD, and the Medical Center Library as sources for this study.

In their book, Business Research Methods, Emory and Cooper support the use of both computerized and library searches (17:285-313). They further note that, "Secondary data may be used as the sole basis for a research study" (17:287). Emory goes on to say, "Periodicals are often the best single source of information for the business researcher" (17:303). One major strength of a secondary

research study is to help determine if the past can make a contribution to the present; the use of secondary data helps to decide what further research needs to be done in a field. Another factor favoring secondary sources is the minimal cost such studies usually entail (17:285-286).

Data Sources. This study relies on information taken from previous studies involving military and civilian operational success. Research about the impact of automation on the civilian and military work force was also used. Sources include journal articles, Air War College papers, and general literature articles on automation and technology.

Information Selection Criteria. Information was sampled based on the bearing the data had on two criteria. First, did the data reflect military success based to some degree on technology? Second, did the data reflect an impact of automation on military or civilian workers?

Method

This analysis uses previous studies to infer a relationship between automated aircraft diagnostics and the degree of technological sophistication of aircraft maintenance technicians. The inference is based on secondary data which shows a relationship between automation and the worker/technician. Previous studies about the impact of technology on military successes and the impact of technology in the work place are used as a data base. The

information inferred from this study is used to suggest possible hypotheses for future study.

Summary

This chapter outlined how data was gathered and why the library search was used to answer the given research questions. Additionally, validity of this research approach is provided. The next chapter is the literature review which provides information required in order to answer the research questions.

III. Literature Review

Organization

This chapter is divided into three main parts. The introduction will provide the reader with a thorough background about the current and projected capability of automated diagnostics and expert systems. The second major portion of this review covers how automation technology has impacted the civilian work arena. Finally, the third part of the analysis will explore literature about the technological traits that have been attributed with success in past combat situations.

Section I. Introduction

This introduction explores published material about aircraft diagnostic systems (including expert systems) in order to give the reader background information about current and projected capabilities of these systems.

Military aircraft must be kept operationally ready. The approach to maintaining an aircraft has significant influence on its downtime, and extended periods of downtime affect operational readiness even more than poor reliability (16:1090). In the face of increasingly complex aircraft, a variety of test and recording equipment has been built into the various systems of the aircraft to assist in detecting and troubleshooting problems (21:1354).

The United States Air Force is faced with two trends which, taken together, portend decreasing performance. These two trends are (1) rising complexity and sophistication of current military hardware, and (2) the decreasing availability of highly trained, highly skilled maintenance personnel. Expert system technology provides a means for countering these trends. It can be applied to capture acquired knowledge and experience in a user-friendly tool which can be looked to for advice by a technician user (14:1335-1336).

Future diagnostics possibilities include the use of data links to transmit avionics fault data and maintenance messages to a ground maintenance system (16:1091). Another proposal is an integrated maintenance information system which will use a portable computer to plug into an interface bus on the aircraft to access fault data and interrogate on-board computers. The system would also automatically update maintenance actions, eliminating the need for technicians to fill out cumbersome maintenance forms (38:1359). A program initiated in 1984 is also expected to provide reductions in CanNot Duplicates (CNDs) and ReTest OKs (RTOKs). Both CNDs and RTOKs waste technician time and resources troubleshooting units that are actually not malfunctioning. This program which develops self-repairing flight control systems has the objective of improving the reliability, maintainability, survivability, and life cycle cost of

flight control systems through aerodynamic reconfiguration and maintenance diagnostics (18:504).

Aircraft Systems. The Air Force has been at the forefront of diagnostics system development. The C-5A aircraft was the subject of the first effort in on-condition monitoring. The C-5A Malfunction, Analysis, Detection, and Recording system (MADAR) monitors engine performance and over 1,000 test points, including avionics, engine vibration, pressure, temperature, and airframe stress. Initially, the monitored data were transmitted to ground stations for processing. Workload and data quality forced a change to this process, however, and data were recorded for later off-line processing using a human quality control interface (16:1090-1091).

The evolution of a maintenance diagnostic system for the F-16A aircraft flight control system is an example of how a small knowledge-based prototype system has grown into a comprehensive diagnostic system. The F-16 Flight Control Maintenance Diagnostic System (FCMDS) has been in development for almost five years. The system performs diagnostics and acts as a maintenance aid to F-16 flightline technicians. One of the major problems of developing this system was the early lack of a laptop portable computer that had the necessary capability to handle large data bases in order to quickly identify failures. One advantage of the FCMDS is the capability to display the cable wiring runs in a graphical format. The graphical depiction of wire runs

shows a signal path from its source to its destination. Assembling the same information from Air Force technical orders requires large amounts of time. Using FCMDS, the information is available in seconds (42:520-524).

An F-15 flight control system prototype diagnostic system has also been developed. This maintenance diagnostic is intended for operational use and can provide hard copy documentation upon request by the technician user. The technician may then take this documentation to the aircraft for reference. This system has been designed to provide interaction with the technician on whatever terms he should choose. For example, a highly skilled technician may choose to consult the system for the purpose of obtaining a checklist of specific diagnostic procedures for a given fault. Less skilled technicians may wish to make use of a variety of support functions which include block diagrams, schematics, explanations, and video stills. The user selects information via a menu which is part of the user's color CRT display. The major objective of the F-15 system is the reduction of RTOK rates that have been experienced on F-15 flight control line replaceable units. The reduction of RTOK rates is expected to occur because the diagnostic uses an expert system which allows even marginal technicians the use of an expert's knowledge (14:1335-1340).

Perhaps the most advanced aircraft diagnostic tool currently in use is the B-1B Central Integrated Test System (CITS). CITS is a sophisticated on-board system that

provides monitoring and testing of approximately 11,500 parameters. Those parameters are distributed among 34 aircraft subsystems. CITS is capable of performing testing and verification of the aircraft's operational readiness, both in flight and on the ground. CITS was designed so that 65 percent of detected failures are isolated to a single Line Replaceable Unit (LRU). Ninety-five percent of the remaining failures are isolated to a group of four or fewer LRUs. CITS uses a coding scheme to report these failures to the flight or maintenance crew. Failures are also recorded on a magnetic tape for future off-line downloading. In addition to providing fault codes, CITS can also be used to query subsystems on their current status. This includes the ability to check circuit breaker and relay information. In-flight monitoring of systems occurs every 30 minutes or whenever a fault is detected (13:500).

The civilian industry has also been pursuing aircraft diagnostics as a maintenance aid. The latest generation Boeing 747-400 has an integrated approach to maintenance using a Central Maintenance Computer (CMC). This system is capable of monitoring more than 140 separate LRUs used in over 70 aircraft systems. It performs this function automatically without intervention from the flight crew. The CMC connects to all major avionics, electrical, and mechanical systems on the 747-400. The CMC collects, stores, and displays maintenance information generated by LRUs. The CMC also provides a single location from which

system tests may be initiated. More than 7,000 distinct fault messages may be generated, and 500 of these may be stored for the last ten flights. The maintenance status from the CMC on the 747-400 is used to determine if the aircraft is in flyable condition or not (45:307-309).

Expert Systems. The promise of expert systems can be especially advantageous for the Air Force maintenance officer who will soon be severely challenged by many new influences. Some of these factors are the increase of weapon systems costs, new advances in technology, reduced defense budgets, and the loss of experienced maintenance technicians. These factors will force the maintenance officer and Air Force planner to seek new ways to reduce the downtime of expensive weapon systems. Expert systems can help do this by reducing the amount of time devoted to troubleshooting. Further, expert systems can analyze problems and can even aid the maintenance technician by suggesting repair strategies. Because expert systems are such a powerful tool, their future uses and impact on maintenance technicians must be addressed today.

This section is divided into five parts. Expert systems will first be defined. Second, the union of expert systems and artificial intelligence will be explored. Third, the development of an expert system in an organization will be addressed. Fourth, to strengthen the concept of expert systems, examples of their use in the civilian world will be given. The last segment, in the

discussion section, gives several examples of the use of expert systems in civilian and military aircraft.

Definitions. Parker defines an expert system as a "software system intended to provide the type of advice that would normally be expected from human experts" (49:810). In other words, this software package attempts to reproduce, though some would prefer the term "mimic," the decision-making abilities of a human expert in some particular field (49:222).

Knowledge-based expert systems are at the forefront of aircraft diagnostics. Exactly what is a knowledged-based expert system? A recent article entitled, "Expert System Maintainability," defines a knowledge-based expert system as:

> . . . a heavily symbolic computer program which has a separate declarative knowledge base and inference engine. An expert system is a specific kind of knowledge-based system, usually built using expert systems tools, technology, and languages. Expert systems best solve specific complex problems, and do so quickly and skillfully using a human expert's knowledge and problem-solving ability. An expert system's declarative knowledge base contains information about the problem area. (11:415)

Artificial Intelligence and Expert Systems. The first definition by Parker is workable but somewhat simplistic. A better definition would have to add that the use of artificial intelligence (AI) is becoming almost essential to the development of expert systems. For example, United Airlines is using an expert system, developed by Texas Instruments (TI), that manages the

assignment of its airplanes to specific gates (53:148). This system uses artificial intelligence that was developed from drawing on the experience of United's systems analysts and gate controllers. By tapping the accumulated experience of a few acknowledged experts in assigning aircraft to gates, TI was able to incorporate this knowledge into a software package. Now, any person working for United can make gate assignments with the same high degree of success that only a few people could do before the expert system was established (53:147-148).

The use of AI in an expert system has been used by the US Army. The Army Logistics Center, with the help of the AI office, has developed an expert system to help maintenance personnel in troubleshooting and repairing the pulse acquisition radar for the Hawk missile system (32:38). This system is called the Pulse Radar Intelligent Diagnostic Environment (PRIDE). The PRIDE system has reduced the amount of troubleshooting needed and, therefore, the downtime of the radar system. PRIDE has been able to do this because its AI system can "learn" from past mistakes. The Army has enjoyed great success with this system. For example, PRIDE has increased the "in-commission" time of the weapon system, reduced the downtime, and decreased the amount of time maintenance personnel must devote to the weapon system. Even more impressive is that these accomplishments were realized in the face of reduced defense spending. Developers of new weapon systems should keep the

success of PRIDE in mind as they design the weapons of the future (32:38-41).

The potential use of AI is virtually unlimited. For example, an automotive computer based expert system (ACE) was developed in the Artificial Intelligence Lab at the University of Alabama. The system is designed on the theory that troubleshooting is the process of uncovering a set of symptoms or identifying a series of quirks that indicates a malfunction exists or is about to occur. Once the potential problem is discovered, the next step is to determine which steps should be taken to resolve the difficulty (43:187).

The ACE can, with the video interface and human operator, analyze information about symptoms. The system will then make decisions about what actions to take and even make inferences about the root cause of the problem (43:188-200).

The use of expert systems and artificial intelligence holds great promise for making maintenance operations in the future more efficient.

Development of Expert Systems. The replication of a human expert's thinking, in an expert system, is the primary goal of developers. However, this by itself is not sufficient to ensure that the maximum use of an expert system is realized (6:46). The best use of an expert system is gained when a strategy mandating the concurrent development of the expert system and the machine it supports

is adapted. Managers must also realize that on occasion it may be necessary to revise and update this strategy (8:461).

Braden's article describes four basic criteria, in the form of questions, to use when incorporating an expert system into a new piece of equipment. These questions are:

1. Is the expert system feasible and can it be justified?

2. Is the risk involved worth the investment of time and money?

3. How many limited resources will be devoted to the project?

4. Due to the relatively new technology involved, how available are the engineers who can design and implement this system (8:464)?

Finn describes, in some detail, the techniques used to develop an expert system (19:5). Specifically, the expert system must have a software package that can make logical conclusions based on information already loaded in the computer. This knowledge base is best derived from a human expert who has had a great deal of experience operating and maintaining the system in question. Also, the expert system must have complete knowledge of the process and control of the operating system it is to monitor (19:5).

Finn's article goes on to describe how the expert system concept has been taken one step further in the chemical processing industry. The expert system is also being used to solve problems related to processing chemicals

in order to make the system more efficient. For example, the expert system is being used to do predictive maintenance or project which system might fail before it actually does (19:5).

A common goal of expert systems is to make them user friendly. This allows a person, who has little training in the operation of the expert system, to make sound troubleshooting decisions and repair the machine being maintained (37:46).

Harris Corporation of Melbourne, Florida, has designed an expert system that can be run on a personal computer. This system is designed for use by nontechnical personnel to troubleshoot the company's IBM computer system (37:46).

The software package can pinpoint hardware failures and even operational mistakes committed by the operator. The program also tracks the status of key components. All of this information is presented in an easy-to-understand, interactive format (37:46).

Traditionally, the Air Force has relied on high school-educated people to do their aircraft maintenance. As the Air Force acquires more technologically advanced aircraft, expert systems will become a necessity to help maintenance technicians. These systems will also reduce the cost of training flightline mechanics. This cost reduction will be crucial in an era of tight budget constraints.

Examples of Civilian Expert Systems. A good example of the use of expert systems in the civilian world

is described by Basham (4:5.1). The author examines an expert system used for scheduling maintenance by the Houston Lighting and Power Company (HL&P). The system is called the maintenance management control system (MMCS). This system has a colossal scope of operation. It is used to schedule the maintenance on ten fossil fuel plants maintained by some 1,400 personnel (4:5.1).

Once every quarter, HL&P does maintenance on its plants which entails shutting down parts of its power producing capabilities for a period of time. The goal of HL&P is to keep this downtime to a minimum. To help reach this goal, MMCS provides three products: a work order, material management, and scheduling systems. The work order is simply a data base that tracks the past maintenance performance of each item of equipment. The material management system will tell the manager and technician accomplishing the task what parts and tools are needed to effect repairs. The last product, the scheduling system, is the system that makes the most use of the expert system concept. The scheduling system will determine which jobs should be done in what order and which jobs can be worked on simultaneously. This system results in an enormous amount of time saved in doing maintenance actions and keeps the amount of plant downtime to a minimum (4:5.1-5.5).

Industry is depending more heavily on the use of computers as time passes. An article written by Janz operates from the premise that computers are becoming a

standard feature in the offices of most businesses today (30:35). With computer systems so closely integrated into daily business operations, computer downtime of any length can cause severe problems. Janz describes the actions taken by the Digital Equipment (DE) company of Canada to resolve this problem (30:35-36).

DE is developing a group of new computer equipment that includes sophisticated monitoring and diagnostic mechanisms. DE is linking monitoring equipment to a VAX system. The monitoring equipment uses artificial intelligence to not only analyze errors but to also make predictions about possible future failures (30:35-36).

The monitoring equipment is linked to all computer work stations and has the ability to trace problems to an individual work station or to a section of the computer network that may be malfunctioning. The monitoring system is tied into a central location called a support center where the diagnosis of a problem, and recommended solutions, are made by a technician (30:35-36).

Graff has written an article that dovetails with the article written by Janz. Graff also contends that business computers are an absolute necessity in the work place and that any downtime of these systems will cause a great deal of hardship on the managers of these businesses (26:19). He says that one way of dealing with this issue is to have on-line spares. However, this option is expensive. An alternative method is to buy computers with built-in

redundancy or "fault tolerant" equipment. Such computers will keep operating even if one system fails (26:19).

However, even this type of equipment needs to be monitored. The advantages of using software that incorporates artificial intelligence is that the software allows maintenance actions to be preventive. Maintenance will also be proactive because the expert system will enable planners to forecast the probable failure of a part and to act to replace it before it causes the entire system to fail. Graff claims that the use of fault-tolerant equipment, coupled with the use of AI, produces a system that is highly resistant to failure (26:19-21).

Civilian Aviation and Expert Systems. The first two articles in this section deal with the growing pains Boeing is having with the maintenance computer on the new 747-400. The first article, written in 1988, describes some management decisions that complicated the delivery of the maintenance computer. The second article was written two years later. It discusses some of the more practical problems Boeing experienced with the maintenance computer.

In 1988, Boeing was in the late stages of developing and flight testing a new 747 derivative, the 400 model (47:34). To try to meet the goal of delivering the aircraft to buyers on time, Boeing implemented an unprecedented flight test program. This program was needed because the project was delayed, in part, by problems in the Central Maintenance Computer (CMU) (47:34).

The maintenance computer is pivotal to updating the 747. This computer will allow for easier troubleshooting and will, therefore, save money in terms of maintenance man-hours. The problems Boeing had in developing the CMU greatly added to the management problems of getting the new aircraft on line (47:34-35).

A management decision leading to this maintenance computer problem was the determination to offer the 747-400 to buyers with three different powerplants. Developing maintenance computer software for three different configurations caused part of the delay for this system. However, this delay had to be dealt with since the maintenance computer is critical to the operation of the aircraft, and also controls operating costs (47:34-35).

By 1990, the new 747-400 had just completed its first year of operational service (48:68). Boeing formed a special team to improve the reliability of the aircraft. One of the factors reducing the reliability of the plane was the CMU which, ironically, was designed to increase the operating efficiency of the aircraft (48:68).

The CMU accepts inputs from 6,000 reporting systems. Boeing's primary problem is poor computer interfaces between the CMU and the various systems being monitored. These faulty interfaces generate false messages. The CMU is intended to decrease turnaround time but instead has increased it because maintenance personnel must try to determine if the messages are legitimate warnings or

fraudulent indications. Boeing has isolated the problem to faults within the software for the CMU (48:68-69).

Managers in aircraft manufacturing realize that on-board maintenance computers are essential to the effective operation of aircraft, especially airframes such as the 747, which can be away from its maintenance base for 30 days or more (48:68). This technology is new and is causing teething problems for the 747-400. These problems are being addressed by a Boeing working group. Boeing feels this effort will be worthwhile in the long run, as end users are exceedingly concerned with holding down maintenance costs through all possible means (48:68-69).

The use of expert systems and maintenance computers is not limited to only the large aircraft community in the civilian world. For example, CTA, Inc. has developed an Automated Maintenance Management System (AMMS) (46:153). This is a new computerized maintenance system that may be able to improve civil aircraft maintenance and reduce costs. The system works by collecting information from a data bus in the aircraft. This data bus monitors the fitness and logs the performance of several aircraft systems. The information is collected in flight on a floppy disk. Upon landing, this disk is inserted into a ground-based computer that has the software to advise maintenance personnel of system malfunctions (46:153).

The ground-based computer is called the Mobile Enhanced Comprehensive Asset Management System (MECAMS). The MECAMS

is designed for maintenance personnel who have little computer experience. The on-board system is made by Sundstrand and weighs only 20 pounds (46:154-155).

Once the AMMS has identified a systems problem, the system will give the technician detailed troubleshooting and maintenance instructions. Even a provision for receiving help through a satellite link exists. This satellite link has great possibilities for military use when units may have to deploy to a remote station on short notice (46:156).

The advantages of a military application of MECAMS are readily apparent. The simplicity of the ground computer and the easy interface between it and the airborne portion of the system make it a friend to the maintenance man.

Expert systems are so flexible, they will soon dominate all facets of the aircraft industry. As one example of their flexibility, expert systems can be used to help manufacture aircraft. Parks maintains that implementing an expert system into a paperless manufacturing-process computer system will reduce the amount of paperwork needed. This paperwork reduction will save time for managers and money for the company (50:36). As the aircraft moves down the assembly line, the information needed by different managers and shop floor supervisors varies. The expert system can "make" decisions as to who or what department should get information and what type of information is needed. The author states that the expert system, coupled with relational data bases, will give managers a powerful

tool in managing complex operations such as building aircraft (50:44-45).

Parks' paper again points out the numerous advantages the expert system offers. It also points out that the expert system should be coupled with relational data bases. Then, the expert system will not only have the "knowledge" of the human expert, but also the data retrieval of computers.

Military Aircraft and Expert Systems. As military aircraft continue to grow in complexity, expert systems will not be considered a luxury but a necessity. This section will review two articles written about the F-16 and the B-1B.

The Integrated Maintenance Information System (IMIS) is a hand-held portable computer that plugs into the F-16. It performs built-in-tests (bits), and reads and analyzes the data. Presently, the IMIS is in the experimental stage (38:1359).

The IMIS has several design goals. IMIS will be able to interface with all existing maintenance information systems and will be able to perform automated diagnostics. The flightline maintenance technician will take the IMIS out to the aircraft and access aircraft systems, run bits, and then compute the most effective strategy for repairing the malfunction (38:1359).

A feature that all maintenance officers and technicians will appreciate is its ability to interface with maintenance

computer data bases, e.g. CAMS. IMIS will have the ability to fill out all of the required maintenance actions, including work unit and how malfunctioned codes. This will greatly reduce the inconvenience to the maintenance technician of filling out cumbersome forms after a hard day on the flightline. IMIS will also ensure that correct data is entered into CAMS (38:1359).

The success or failure of IMIS will have a great impact on the maintenance community. A system that can help in diagnosing problems and can interface with CAMS is needed to streamline the job of the flightline mechanic (38:1362).

Expert systems can be a double-edged sword. They must be designed carefully or they have the possibility of causing more maintenance work instead of less. For example, Stanley states that diagnostic equipment already installed on aircraft, such as the B-1, has been costly to maintain. However, he also states that the potential to greatly reduce the cost of maintenance is worth the money and management risk (56:1351). The primary way expert systems can reduce maintenance costs is that the expert system has the knowledge and experience level of a skilled maintenance technician and can be utilized by less skilled personnel 24 hours per day (56:1351).

Stanley goes on to describe desirable characteristics for flightline diagnostic systems. First, the expert system must be light. On any aircraft, weight and size are limiting factors. Size and weight are also a limiting

factors for the maintenance worker. Past experience shows that large, heavy pieces of maintenance diagnostic equipment will rarely be used by the flightline technician (56:1352).

Second, the expert system should work both on the ground and in the air. The expert system can be installed on older aircraft or on an ad hoc basis with somewhat limited success. However, on future weapon systems the expert system must be designed into the airframe from the inception of design work. This expert system should also be capable enough to reduce the amount of ground-based support equipment. Finally, the support system should be able to generate work orders and order spare parts (56:1352).

This review discovered several recurring issues common to all articles. Namely, expert systems, coupled with artificial intelligence (AI), will reduce maintenance costs and diminish the scheduling workloads for managers. Researchers make this claim because these expert systems, with help from AI, will be able to "learn" from past mistakes and will have access to the heuristic knowledge of a human expert. Experts agree that as operating systems become more complex, the requirement for a maintenance expert system will be essential to reduce costs. These expert systems are possible today because of the great strides being made in the development of computer software and hardware.

Another area of agreement is in the way expert systems should be developed. Again, subject matter experts agree

that expert systems should be designed and integrated into the operating system they will monitor from the genesis of the system. Expert systems should be designed to be very user friendly since a primary purpose for them is to reduce the skill level of the technician needed to service the operating system.

Finally, there is agreement that the expert systems should work for the human and not pose more problems than they solve. For example, the maintenance computer on the 747-400 and on the B-1B generate many false work orders, and the maintenance technician must spend numerous hours determining if the indicated malfunction is a valid problem.

The advent of expert systems moves maintenance into a new realm. Instead of being reactive, or at best preventive, maintenance can now be proactive. Expert systems in the future will have the ability to predict, based on past histories, what parts or systems are about to fail.

However, many unanswered questions remain on this topic. In reality, there may be a black lining behind this silver cloud. One major issue that needs to be addressed is the impact expert systems will have on the maintenance technician. If an expert system is developed to the point that all the maintenance technician needs to do is read messages off a touch-sensitive screen and remove and replace a box the maintenance computer tells him to, how do we, as managers, keep such a person trained and motivated? These

critical maintenance related questions are addressed in Chapter V. The next section explores the capabilities of future diagnostic systems.

Projected Capabilities. Advances in aircraft diagnostics over the past decade have been nothing short of phenomenal. These advances raise the question of what the next 10 or 20 years bring. Three possibilities are real-time data links from aircraft to ground maintenance systems (16:1091), personal computer-based plug-in diagnostic tools (38:1359), and self-repairing systems (18:505).

Real-time data links from in-flight aircraft to ground maintenance systems can result in quicker aircraft turnaround time. Aircraft turnaround time in a combat situation is critical and is a limiting factor in the number of sorties an aircraft can produce. If the weapons system could be monitored in flight, maintenance could be available with the correct part to fix the malfunction when the aircraft lands. An added advantage to a data link would be that maintenance could further diagnose an in-flight problem to isolate the malfunction to a specific component. Many CNDs are caused because the ground technician cannot duplicate the stresses of flight on the aircraft. The civilian aircraft industry is already using a system to down link engine data on a real-time basis. An expanded form of this system could be used on military aircraft to help speed aircraft turnaround time (16:1091-1093).

Another future for aircraft diagnostics involves the use of personal computers loaded with expert systems which can be used to directly plug into aircraft data buses. These systems could diagnose faults, recommend corrective actions, and check supply to see if parts are available all at once. The computer would even provide the technician with a list of necessary tools required to perform the repair. A scenario might involve the technician plugging into the aircraft data bus and simply following the directions of his user-friendly computer. After the job is completed, the technician would not have to complete paperwork because his computer would automatically upload the required information to a mainframe system. This would eliminate paperwork mistakes (38:1359-1361).

Perhaps the ultimate diagnostic will be the system that not only fault isolates a problem but also reconfigures the system for optimum performance by isolating the bad component. The Self-Repairing Flight Control System (SRFCS) program is one project working toward that goal. The Mean Failure Time Between Flights (MFTBF) for F-15 and F-16 flight control systems has traditionally been between 25 and 50 hours. The mean time to diagnose the problem is eight hours. Compounding these short MFTBF and long troubleshooting times, 34 percent of the time a part is removed and sent in for repair, the part tests good. The SRFCS hopes to eliminate both problems by using an expert system which troubleshoots the problem and reconfigures the

aircraft for optimum performance by bypassing the bad part (18:505-509).

Section II. The Effects of Automation on Workers

The civilian industrial community is constantly implementing new technology into the work place (44:79). Automation in some form has affected 40 to 50 million workers in the United States. This is almost half the U.S. work force. Automation has de-skilled some jobs and made others more challenging (28:70). Military planners must pay attention to the lessons learned by civilians. Air Force planners must realize that there is a human side to implementing new technology. For example, Tichy states that:

> Technological innovation is not solely a technical change; rather, it is social change affecting the behaviors of individuals and groups within the organization, and it is structural change that alters the information flows and work designs of the organization. (57:61)

This same view is held by Mayer, who maintains that:

> Because the technical aspects of innovation are engineering related problems, managers and designers tend to focus more readily on technical aspects rather than the social or structural dimensions of change. (41:121)

Research shows that the implementation of automated systems is not solely a technological issue. Successful implementation requires the inclusion of personnel issues in the development of automated systems.

Current research indicates that little is known about how workers adjust to technological innovations (44:79;

2:1184). When researchers have explored the issue of job satisfaction after the implementation of new technology, they have come up with varied results. For example, Form reports increased satisfaction (20:177) while Kraut reports decreased satisfaction (34:236-238), and others report no change in job satisfaction levels (1:39-40).

There is also disagreement among researchers about how workers will perceive new technology. Attwell and Rule maintain that "most workers surveyed regard the new technologies in a positive light" (2:1187). However, Krevnevich reports that workers in the western world continually view automation as a threat (35:61).

Present research would seem to indicate that it is impractical to try to make blanket statements about how workers will react to automation. It seems that workers will respond to new technology based on several factors. These factors include education and job position.

Job Characteristics. While researchers have not been very successful in predicting what impact automation will have on workers or how they will react to changes, they have had more success in other areas. The effect of automation on job characteristics is one of these areas. Research literature suggests that workers who feel they have a job that is rich in positive job satisfaction characteristics feel more threatened by automation. These same workers also report the higher rates of job dissatisfaction after the implementation of new technology. Conversely, workers who

have mundane, unskilled jobs will gain more if the introduction of automation requires the use of higher levels of technical skills (44:84). Nelson concludes from this that:

> Simply measuring perceived job content following technological change is not sufficient; what is needed is an examination of the way in which perceived job characteristics change over the three-stage process of initiation, implementation and institutionalization. (44:84)

Attwell and Rule define two extreme positions when describing job characteristics and quality of work: de-skilling and upgrading. De-skilling holds that automation:

> is used to strip relatively skilled jobs of their conceptual content. Those conceptual tasks previously integrated into work are either built into computer algorithms or transferred to a numerically smaller number of high level specialists. (2:1185)

Ultimately de-skilling will produce:

> a mass of unskilled clerical workers at the bottom, and a small number of conceptual workers at the top, alongside management. (2:1185)

On the other hand, upgrading suggests that the introduction of automation increases the degree of job satisfaction of the worker. This is based on the view that many jobs that have been automated have been routine, mundane jobs.

Attwell and Rule describe several case studies where both types of responses to automation have been reported. The authors conclude that both schools of thought may be correct and that both de-skilling and upgrading may occur after the automation of jobs. The response which will occur

is dependent on the skill level of the workers before automation and how the new technology was introduced into the organization (2:1185-1187).

Psychological Impact of Automation. Hockey, et al., reviewed the workload and stress factors involved in job characteristics. They state that:

> job strain is associated with a mismatch between work demands and opportunities, on the one hand, and the individual's resources and needs, on the other. (27:1402)

If demands are placed on a worker that exceed his "resources and needs," then the worker may experience some strain symptoms, such as "physical ill-health, and reduced psychological well-being" (27:1402).

Hockey reports that loss of controllability, and therefore increased worker psychological stress, occurs when the human worker has been "designed out" of the computerization process. Under these conditions, workers tend to lose the chance to use their professional skill, become detached from their jobs, and report lower levels of job satisfaction (27:1412).

These findings are confirmed by Nelson's study. For example, she states that:

> Increased strain appears to result not from the introduction of technology itself but instead from the changes that occur in job characteristics and the psychological aspects of work. (44:86)

Hockey suggests that the way to reduce the possibility of suffering these strain symptoms is to give the worker the "opportunity for control" over his assigned task (27:1403).

Hockey defines this controllability as "the extent to which it provides the operator with the opportunity for exercising discretion in the planning and execution of work activities" (27:1403).

Brooks and Maccoby report a difference in the way professional and semi-skilled workers react to new technology. Professionals, who use computers as a tool to enhance the capabilities of their minds and creative abilities, report more satisfaction and much less strain when new technology is introduced. They note:

> Lower level personnel who use the same type of equipment to perform under detailed supervision repetitive services, whose substance they are not expected to understand, show both health and stress symptoms. (9:44)

Brooks and Maccoby further support this conclusion by reviewing the effects video display terminals (VDTs) have had on workers in the automobile production industry. They report that "Stress connected with the use of VDTs is inversely related to the degree to which the terminals are used as a tool" (9:44).

Research conducted by De Pietro confirms the conclusions of Brooks and Maccoby. He writes that:

> Low skilled workers are more likely to react negatively to the introduction of advanced technology, whereas skilled workers are likely to react positively to it. The reason is that the jobs of skilled workers are likely to involve more judgement and provide more challenge; since they tend to be used interchangeably and across functions, their jobs are also more varied and less boring. (15:6)

A comprehensive article, detailing the psychological impacts of automation, was written by Schrami. The

introduction of computer systems, not designed with the worker in mind, has produced many adverse effects in workers. Some workers have even resorted to sabotage. She reports cases where "honey was poured into one computer terminal, while another was fed a set of car keys" (52:149).

Schrami gives several reasons why workers fear automation. The first reason she gives is that:

> Automated systems, and computers in particular, have been feared and disliked because many perceive them as cold, metallic, and the servant--the tool--of the rich and powerful. (52:150)

Because of this perception, she reasons that a person who interacts with humans as part of the job will feel especially uncomfortable with the introduction of new technology such as automation (52:154).

These findings are supported by research accomplished by Argote. She reports that automation often reduces the opportunity for workers to interact with other humans. She notes that "A decrease in the opportunity to interact with others is generally associated with increases in worker alienation, stress, and absenteeism" (1:32).

Workers also resent the imposition of automation because they feel it dehumanizes them and their jobs. Workers also feel "physically endangered and economically victimized by vast technological systems over which they have no control" (52:150). Some loss of control and feelings of dehumanization are due to:

> aspects of automation including its unrelenting pace, its intolerance of human error, and the requirement that its operators communicate in a coded language. (52:152)

Coupled with these dehumanizing factors is the fact that people must communicate with computers in an artificial manner. The way workers must communicate with the computer is different than the way people communicate with each other. This increases the tensions felt by workers when faced with new technology (52:152).

Schrami holds that part of the reason workers may feel alienated from computers is because workers "lack understanding of the new technology" (52:152). A major contributor to this lack of understanding is the specialized jargon and terminology used by information systems experts (52:152).

Workers also fear automation because it could mean losing their jobs and losing the chance to progress professionally. Schrami states that, "When technological change is mentioned, the first thing many people think of is unemployment" (52:151). A negative organizational atmosphere can quickly occur when workers, who lack technical knowledge about the system being introduced, perceive that this new technology may rob them of their jobs (52:150).

Finally, Schrami concludes by saying that the root fear people have in dealing with new technology is a fear of obsolescence. People fear both that their jobs and even they themselves will become outdated (52:155).

Many of Schrami's conclusions are supported by a research paper authored by Mainiero. She reports that workers' foremost fear of automation is that they will lose their jobs. Along with this fear, she reports that workers often worry about incompetence. Workers, when faced with new technology, wonder if they will be able to learn how to run the new expensive piece of equipment. She states that this fear is especially noticeable in older workers (39:34). Because older workers show higher levels of anxiety to new technology, they also tend to resist change more than younger workers (39:34).

Mainiero also warns that the thoughtless application of new technology by management can lead to:

> fears of helplessness . . . after a new technology is introduced. Workers may feel powerless and out of control of their lives because the work place is changing so rapidly. (39:34)

To lessen these fears of helplessness, Mainiero suggests that a thorough training program be implemented before the full introduction of the new technology. She warns that without this training, "employees often resist changes in the work environment, and morale and job satisfaction decrease" (39:34).

The Argote paper also points out how new technology is introduced must be carefully thought out by management. She notes:

> If the change [of work activities] decreases variety, autonomy, and challenge in jobs, or if it introduces activities that are incompatible with the worker's abilities and preferences, workers' attitudes will

> probably become more negative and their motivational levels are likely to fall. (1:32)

Baldwin also warns that new technology is a double-edged sword. He maintains that new computer technology is found in all facets of life. He states that new technology has brought about great advances in many areas, including communications and health care. However, he maintains that there is a down side to these advances (3:94).

Baldwin, writing about the influence of new technology, states:

> This influence is at once both elusive and powerful in its psychological effect, but it is not well understood. With the passage of time, and as sophisticated technology becomes even more a part of life at work and home, the potential for its negative impact increases. (3:94)

Even the "successful" implementation of automation can cause job stress to workers. Liker reports that some workers reported increased stress because more pressure was put on them by management to produce more with fewer workers. Liker writes, "It was common to hear of workweeks exceeding sixty hours" (36:38). When workers are suddenly confronted with new technology and are forced to produce more with fewer workers, it is not surprising that morale will decrease and job stress increase (36:38).

Research is not clear on what effect automation will have on workers. Researchers also have not developed a good model to predict how the introduction of new technology will affect the individual worker and the organizational structure. However, the research is clear that new

technology must be carefully introduced to the work environment. Without careful implementation, many diverse adverse effects may develop that will lower workers' morale, lower their productivity, and increase job-related stress.

Successful Implementation of Automation. The previous section of this literature review discovered that automation is a double-edged sword. If little thought is given to implementing new technology, workers may have varying degrees of difficulty in accepting changes in technology. However, if careful thought is given to implementing new technology, and a well-executed plan is followed, then technology will be able to realize its full potential. For example, Brooks states, "Companies that conceive of technology as a tool rather than as a substitute for labor show continual improvements in productivity" (9:43). This section will review literature describing how new technology and automation have been successfully implemented in civilian industry.

Integrating Psychological Demands with Technological Conditions. Organizations that report the most success in implementing automation have used "sociotechnical" planning. Hoerr defines sociotechnical planning as, "integrating the psychological and social needs of workers with technological requirements" (28:71).

Brooks describes how Volvo used sociotechnical planning in production plants (9:43-44). Volvo eliminated the traditional assembly line and created different work

stations. Each work station is assigned several workers. These work stations give each worker more opportunity to be a craftsman and to exercise his creative talents. Volvo reports a 15 percent increase in productivity with this new work station concept (9:43-44).

Brooks notes that in the past, managers and engineers have almost always poorly estimated the skill levels required by workers who will interface with new technology. Brooks states:

> As computerized production systems--whether in offices or factories--increasingly integrate a variety of unit operations into a tightly interdependent system, each worker will have to have a more fundamental understanding of the system as a whole. (9:43)

Brooks, referring to the Volvo experience, ends his article by stating:

> Where technology is visibly used to augment the intellectual powers of an individual, the quality of working life is improved and the individual is more highly motivated and responsible; where it is used to mechanize low-skill or routine and repetitive work, symptoms of psychological stress appear and performance steadily deteriorates. (9:44)

Hockey's article asserts that the careless introduction of automation can cause loss of "controllability" on the part of the human operator (27:1412). Hockey states that this loss of controllability most often occurs when "the human operator appears to have been designed out of the decision-making process" (27:1412). Hockey submits:

> High levels of automation in process control jobs inhibit the use of discretion because they remove many options for the human controller, including the opportunity to use professional skills and to actively manage the process. Not only is the resulting detachment from the task experienced as boredom and low

> satisfaction but it prevents the operator from maintaining an effective mental model of the plant or process. (27:1412)

Hockey's paper clearly shows that as much thought must go into the design of the human/computer interface as goes into the development of the hardware and software of the automated system.

Schrami unequivocally states that the psychological needs of the worker must be considered when developing new automated systems. She notes that, in most cases, little thought was given to the impact of new technology on the worker by the engineers who designed the system. Her paper indicates that the most important step which management can take in developing and implementing automated systems is to include the workers in the design phase. She states:

> in order to successfully introduce and implement automated systems, with a minimum of negative psychological impacts, office workers, operators and users should be allowed meaningful participation in the design and implementation phases of automation. (52:155)

Schrami notes that the use of automation will continue to increase in the future. She argues that workers will have to learn how to adjust to this new way of doing their jobs. To help workers adjust, Schrami recommends that management appoint "a highly placed information technology staff member who is charged with the responsibility of implementing automated systems" (52:155). This staff member would provide an interface between the engineers developing the system and the end user. After implementation of the

new system, this staff member would ensure swift resolution of operator/computer compatibility problems (52:155).

Hoerr agrees with the need to consider the psychological needs of workers when developing new automation systems. He maintains that managers should give their workers more input to job design and the design of the automation system. This worker involvement will allow companies to, "adjust much more easily to fast changing market and political conditions" (28:74).

Hoerr quotes Harvey F. Kolodny, a professor at the University of Toronto, as saying, "We should design jobs so that workers can be more than a pair of hands behaving in a mechanical way" (28:74). Hoerr backs up this statement by describing actions taken by Shenandoah Life Insurance Company when it implemented new high technology. When the new technology was first introduced, no savings in labor costs were obtained. Shenandoah determined the problem was with the bureaucratic maze in the company. To remedy this problem, Shenandoah created teams of clerks of from five to seven people. Each team now does the same job for which different branches were previously responsible. These teams allow workers to develop many different skills and make better use of new technology. As a bonus, workers reported higher levels of job satisfaction (28:70).

Nelson adds her voice in support of dealing with the psychological impact of new technology on workers. She states:

> To design and manage information technology innovations that enhance human capabilities, MIS practitioners must cope with the social and political issues as well as the technical issues that surface during transitions. (44:88)

Volpert's research also supports the idea of including the human equation when developing and implementing new technology. In his study, Volpert compared the impact of automation on work tasks. He concludes that, "Practical experience with flexible production automation has provoked rising demands for human oriented job design" (58:881).

Finally, Mainiero reports that senior management rarely considers the social and psychological needs of workers when planning for implementation. He reports contacting six companies who had recently introduced new technology. Of the six companies, only one had sought input from the workers who would be affected by the new automation systems. "Too frequently, management decides to adopt a new technology without adequately considering and planning for human resources factors" (39:32). His study detected two common themes among the companies contacted. They are:

> First, the decision to adopt a new technological system often is made by upper-level management; employees and lower-level managers are told about the change after the fact. Second, technical training usually is provided to help employees learn how to use the new equipment, but little attention is paid to the effects such changes may have on the employees themselves. (39:32)

Obviously, management must pay attention to the social and psychological needs of workers who must deal with new forms of technology, including automation. This is just one recommendation for managers who seek to realize the full

potential of expensive new technology and of their employees. Some further recommendations suggested in literature are detailed in the next section.

Recommendations for Managers. The wise manager recognizes the powerful influence of the introduction of new technology into the work place. Research indicates that there are several measures the manager can take to reduce worker stress and help insure the successful introduction of new technology.

Argote studied the effects of introducing automation, in the form of robots, into the work place. He offers five suggestions to managers about how to successfully introduce new technology (1:39-40). Argote's first suggestion is to resolve questions in the minds of workers about job security and pay. Some might say that job security would not apply to the military man. However, with the recent dramatic budget cutbacks, military personnel are becoming increasingly concerned about their jobs. Argote maintains that the failure to settle these issues before new technology is introduced will most probably reduce the effectiveness of the new automation equipment (1:39).

Argote's second suggestion is to appraise the present state of the organization. Without this appraisal as a baseline, it would be nearly impossible for managers to project the impact of the introduction of new automation technology. Argote suggests that:

> Managers must anticipate potential problems that the change may bring--both obvious problems (e.g., job loss) and subtle ones (e.g., new job activities). (1:39)

Liker takes Argote's suggestion one step further. He states that the introduction of new technology will change the present organizational culture. He further recommends that management be aware of this change and be proactive in introducing or at least directing this change. Liker suggests that when management takes steps to insure a stable change in culture, workers' stress and negative reaction to new technology will be kept at a minimum (36:42-45).

Argote continues by recognizing that management must pay careful attention to the psychological and social needs of workers. He flatly states that management "must develop a strategy for worker involvement in introducing the new technology" (1:39). Unfortunately, Argote notes that very few companies took this step before and during the introduction of new technology. He judges that involvement by management is "likely to increase understanding about the robot and may perhaps lead to greater commitment to the change process" (1:39).

Communication between management and workers is vital after the introduction of new technology, according to Argote. The author notes, "Some feedback mechanism to monitor communication effectiveness in introducing this technology is necessary" (1:39). Ineffective communication, coupled with technologically-induced stress, can drive a deep wedge between management and the work force. This

wedge will reduce the productive usefulness of both new technology and employees and could result in a huge amount of wasted capital investment (1:36-37).

This need for effective communications is supported by research conducted by De Pietro. The author writes:

> Changes in communication and interaction will largely be associated with increased job satisfaction, job influence, and job control, the exception being communication and interaction that leads to closer supervision. (15:9)

De Pietro also states that increased communications raised the job satisfaction levels of skilled workers.

Argote's fifth suggestion to management is for managers to make good use of first-line supervisors. The author notes that workers are much more likely to seek guidance and help from their immediate supervisors when problems occur. Accordingly, management must make an effort to enlist the enthusiastic support of first-line supervisors. With this support, "the attitudes and behaviors of supervisors are likely to have a big effect on the success of the robot introduction" (1:39).

All these suggestions will help management realize the full potential of new technological systems and reduce the degree of worker resistance to change. Perhaps one of the most important measures which management can take is to implement a thorough training program for operators dealing with new technological systems. The training aspect of successfully introducing new technology will be addressed in the next section.

Training Employees. John E. Jones, Executive Vice President for Instrumentation and Automation for Gould, Inc., wrote an article relating training and the introduction of automation. Jones states that much planning goes into the introduction of new high technology. However, "the job of training people to use them is all too frequently an afterthought" (31:14). Jones maintains that upper management has focused so intently on the potential abilities of new technology that the human resource equation is often ignored or dealt with only lightly. With this in mind, Jones warns:

> the productivity of advanced equipment and systems can be undermined by inadequately trained managers, operators, and maintenance personnel who do not know how to operate their own equipment. (31:14)

Most businesses see training as a cost. However, Jones points out that management should view training as an investment rather than a cost. Jones states, "The first order of business is to make training a continuous, instead of a one-time-only or occasional, experience" (31:14). Jones would agree with Gotz, who states, "People can be more flexible than hardware or spares" (25:33). Quality training will multiply flexibility in workers and provide for greater employee productivity (31:14).

Jones strongly recommends that during the early stages of considering which type of automated system to buy, training considerations be estimated. In deciding which type of automated system to buy or develop, Jones recommends that management ask the following questions:

> How much training does the equipment require? How will training be administered? What will it cost? Can the training be integrated over the long haul to bring new workers up to speed and retrain existing workers? Are the training materials flexible enough to accommodate technology changes? (31:14)

Skilled workers will be much more in demand as the systems they operate become more complex. Jones states that the investment in training workers will pay off over time. He concludes by saying:

> Hand in hand . . . increasingly skilled employees will propel the leading manufacturing firms of today into tomorrow with optimal productivity and a measurable impact on the bottom line. (31:14)

Even though Jones' comments were directed toward the civilian industrial community, many of his recommendations and warnings apply to the Air Force. With the reduction in personnel and budget, military planners must be as concerned about the "bottom line" and personnel training as are our civilian counterparts. For example, Holland conducted a study for the U.S. Navy on the use of automatic propulsion plants on board ships. Holland states that the Navy's incorporation of automated propulsion plants increased, rather than decreased, the need for highly qualified personnel. Holland recounts how the Navy had to do a review of current propulsion plants to "ensure that designs being introduced into the fleet are not overly complex or overdesigned" (29:A 1-4). The crux of Holland's article is that personnel training for new technology is absolutely essential. Without this training, new automation systems can very well become a millstone rather than an advantage.

Holland recommends that the following constraints be dealt with when purchasing or designing new automation systems: training support facilities for personnel, skilled personnel availability, maintenance capability and strategies, and supply support. Based on these constraints, Holland warns:

> While it is clear that the technology exists to design very sophisticated "automatic" propulsion control systems, it is also clear that the related biotechnology must be consistent with the above constraints and, as a result, full utilization of automation technology in all likelihood will not be achieved. (29:A 1-4)

Mainiero describes the trials of one company that neglected to provide adequate training for its employees after introducing new technology. The company provided training, but only for one day, and the quality of the training was questionable. Company management thought that on-the-job training and reference manuals would round out employee education. To further complicate the situation, the new automation systems were quickly introduced, further adding to worker stress (39:32-33).

Mainiero recounts that productivity levels of employees immediately decreased and, even after several months of operation, productivity still had not returned to original levels. Also, "morale and job-satisfaction levels decreased markedly" (39:33). Mainiero concludes her study by saying:

> In short, management inappropriately planned for the change causing some resistance from the secretaries and providing the foundation for many human resources problems later on. (39:33)

Research clearly indicates that automation is a powerful tool. It can greatly increase worker productivity and make a business more competitive. Research also clearly shows that careful planning, design, and introduction of new technology is critical to the organization. This section has provided measures that management can take to ensure the successful implementation of new technology. If civilian and military strategic planners fail to heed these recommendations, the realization of the full potential of workers and new automation systems will probably not be met.

Section III. Technological Success in Combat

In an age when military thinkers stress the technology of war--the killing power of modern weaponry--it is often forgotten that the effectiveness of any weapon, no matter how destructive, ultimately depends on the ability of a single human being or small groups of human beings to operate that weapon. Technology, no matter how destructive, will never obscure the role of the human element in achieving success on the battlefield (23:1).

This section is divided into four parts. The first part examines why technicians working far from the front are affected by combat stress. The second part investigates what happens to technical ability in combat. Traits and factors that have been critical to technical success in past combat situations are explored in part three. Education and training, intelligence, and cohesion/morale are discussed as factors that contribute to effective performance. The final

part of this section relies on a historical account to demonstrate traits which were critical to the operational success of the United States forces in World War II. This account was compiled by an Army Air Corps officer who believed a large portion of the allied success in the war should be contributed to the innate ability of the maintenance technicians of the time.

The exploration into the above areas is necessary in order to make inferences regarding the impact of automated diagnostics and expert systems on the traits of technicians who, in the future, will be required to perform under combat stress. Also, by examining those traits that have been successful in the past, it becomes possible to speculate on the potential of future technicians based on the presence or absence of given traits.

Why Technicians will be Affected by Combat. Even though Air Force technicians who will work with automated and expert systems will seldom see front-line combat action, they will still experience the stress of combat. An article published in Military Psychiatry notes:

> The Yom Kippur War of 1973 demonstrated that logistics troops in the Israeli Defense Force (IDF) were at peculiarly high risk for psychiatric casualties in proportion to physical casualties. The bulk of these casualties took place in units that were subject to enemy medium- and long-range artillery fire as well as air attack. (23:14)

Even more recently, Cable News Network's (CNN) coverage of the 1991 Gulf War demonstrated how military units and civilian populations experienced the stress of combat while

being far removed from the front. Scud missile attacks (or the threat of missile attack) became a constant stress factor.

Air Force fliers and base personnel are in a unique position to experience combat stress. In "Combat Stress Disorders and the U.S. Air Force," Rundell cites a number of factors that heighten Air Force combat stress vulnerability. Among these factors are: (1) the passive nature of combat duties, (2) relatively small amounts of combat skills training, (3) family proximity to potential operational areas, and (4) base and personnel immobility. Rundell notes that Air Force bases are becoming more vulnerable to attack. This new vulnerability comes from heightened threat of ballistic missiles, high-speed aircraft, and chemical/biological attacks (51:515).

In accessing the threat of combat stress, Rundell makes the following statement regarding Air Force personnel:

> The passive nature of combat duties for most Air Force individuals (unarmed nonflying support personnel) makes them more vulnerable to combat stress reactions and psychiatric disorders than their Army and Marine counterparts, who may actively defend themselves. (51:517)

Stress in individuals in the Air Force is greater for several reasons. First, in some cases, members' families may be living on or near the base. The threat of family members being involved in a combat operation can be real. Additionally, communications with family members, even those close to the work area, may be severely hampered. Second, the threat of chemical and biological warfare has become

genuine. Use of protective gear creates additional hazards for the technician. The main concern is that chemical gear contributes to the physical stress on the individual. Mental stress is also heightened due to fear of the toxic agents. Third, the fact that Air Force bases are typically fixed also increases combat stress. These fixed bases instill a feeling of being a "sitting duck" (51:517).

Previous sections have explained why combat represents a different work environment and why support personnel will be affected by the stresses related to working in a combat situation. The next section will illustrate what happens to technical ability in combat. Of prime concern is the ability of individuals to perform complex troubleshooting and repair procedures.

Resultant Effects of Combat. Traditionally, the effects of combat have been measured on front-line troops. The intensity of modern warfare has introduced a level of mental stress which was incomprehensible prior to the Civil War. In World War I, the term shell-shocked was first used to describe an individual who could no longer function mentally. Stress levels on the technician removed from the front line will impact his ability to perform.

Articles describing the effects of combat stress on front-line soldiers are abundant. For example, Marlowe, in Military Psychiatry, reviewed the effect of combat on troops involved in the D-Day invasion. He notes that the initial period of combat was accompanied by severe anxiety. At

about 25 to 30 days, soldiers demonstrated abnormal fatigue which could no longer be relieved by rest periods as long as 48 hours. Fear reactions became more frequent and were more difficult to remove. The soldier began to lose confidence in himself. He began to lose the fine points of discrimination. For example, he could no longer differentiate between friendly and enemy shell fire. After 40 days, the soldier became slow-witted and slow to comprehend simple orders. Memory defects became so severe that the soldier could not be relied on to relay a simple order (23:10-11). These symptoms appeared in troops who were constantly exposed to enemy fire. To say these symptoms would occur at the same time or severity in troops in the rear area would probably be unrealistic. However, since the point has already been made that support personnel away from the front are affected by combat stress, some lessening of skills in those troops should be expected.

One area in which the combat situation can be expected to dull performance occurs when sleeplessness due to stress begins to impact worker performance. Haslam and Abraham conducted sleep deprivation exercises to determine the effect of lack of rest on soldiers' performance. A nine-day field exercise was carried out to demonstrate the effects of sleep deprivation. This exercise, "Early Call I," divided a parachute regiment into three groups. The groups were scheduled for 0 hours, 1 1/2 hours or 3 hours of sleep per 24-hour period (5:167).

The 0-hour sleep group was removed from the exercise after four days because the observers felt they could no longer perform even the most rudimentary of tasks. All groups were required to perform vigilance shooting and encoding exercises each day. All three groups showed marked decreases in performance after sleep deprivation (5:167-171). In summary, the results for the exercise revealed the following:

> 1. Soldiers are likely to be militarily ineffective after 48 to 72 hours without sleep.
>
> 2. The effects of sleep loss are mainly psychological: mental ability and mood deteriorate, whereas physical fitness does not.
>
> 3. Tasks requiring cognitive ability, especially sustained attention, are likely to be impaired after sleep loss. (5:175)

Shooting and encoding are representative of simple technical tasks. The same effects of sleep deprivation could be expected to occur in any area involving technical expertise.

Another effect of stress on maintenance performance that occurs is the lengthening of time required to perform a task in a stressful environment. Klein and John studied the effect of stress on workers by examining case studies in which workers were placed under great personal stress (similar to combat stress). In one example, a welder was required to seal leaks in a tube which was leaking CO gas (CO can cause suffocation). Normally, the task could have been performed in 12 hours. However, the job took 36 hours because the worker was under more stress (33:14).

In another instance, an oil refinery worker was tasked with replacing a blocking valve. Routinely, the job took ten minutes. However, a fire three feet away from the valve placed additional stress on the worker and the job took 37 minutes (33:14).

The impact of combat stress on technical ability must be minimized. Studies have shown certain traits/factors combine to create individuals who perform better under combat stress. The following section will review those factors.

Traits Indicative of Superior Combat Effectiveness. Since the end of World War I, much effort has been invested in determining criteria that accurately measure combat effectiveness. Assessment techniques range from the use of extensive tactical evaluations to sophisticated simulation projects in the area of operations research. Ultimately, the only real measure of combat effectiveness is unit performance in battle. One way to determine what makes an individual effective in combat is to examine the past experiences of operational organizations.

Many studies have attempted to identify traits which are indicative of good performance in combat and high stress situations. Typically, the studies propose several factors that contribute to effectiveness. Three factors seem to emerge as dominant predictors of effective performance: (1) education and training, (2) intelligence, and (3) unit

cohesion. The following three sections will explore each of these factors relating to combat effectiveness.

Education and Training. The purpose of training is to ingrain into the soldier the skills necessary to effectively perform his job. One early proponent of training was General George S. Patton. In 1918, he wrote:

> The object of all training is to create a Corps d'elite, that is a body of men who are not only capable of helping to win this war, but are determined to do so. It cannot be emphasized too often that all training, at all times and at all places, must aim at the cultivation of the OFFENSIVE SPIRIT in all ranks... (7:67)

Patton believed that the skill soldiers gained from training would have a direct result on the battlefield (40:29).

Charles Marashian completed a graduate level thesis at the Naval Postgraduate School studying the effects of various human factors on battlefield effectiveness. One factor he considered was the impact of training on combat troops. His methodology involved surveying U.S. Army infantry officers in the rank of lieutenant colonel who had command combat experience in Vietnam. The commanders sampled represented mechanized, airborne, airmobile, and light infantry structured units (40:39).

The commanders were each given 45 statements about human factors that affect combat effectiveness. The respondents were asked if they agreed or disagreed with each statement (based on a scale of from 1 to 5). The respondents were also asked to rank order the importance of

nine human factors relating to combat effectiveness and the will to fight (40:40).

The results of Marashian's study indicated that training was second only to leadership as a human factor related to combat effectiveness. The respondents in the study considered training to be an important factor in preparing soldiers to perform effectively in combat (40:60).

Other authors have noted changes in modern combat and the effect of training on performance. In a research report conducted for the Canadian Army, Major C. A. Cotton notes:

> The marked trend toward specialization evident in World War II has been compounded since 1945 by the accelerating pace of development of military technology and by support and logistical demands of maintaining large overseas forces. Increased specialization has altered the internal structure of the armed forces, incorporating new managerial and technical roles. (12)

Cotton also states that when a soldier has received thorough and practical training, his confidence increases, which helps to counteract the fear generated by combat stress (12).

Intelligence. Webster's dictionary defines intelligence as:

> 1. (a) The ability to learn or understand from experience; the ability to acquire and retain knowledge; mental ability; (b) the ability to respond quickly and successfully to a new situation; use the faculty of reason in solving problems. (59:954)

Obviously, these characteristics would be desirable in a combat troop.

In a paper presented at the Third International Conference on Psychological Stress and Adjustment in Time of

War and Peace, Solomon and Noy state that another factor correlated with decreased performance under combat stress is intelligence. Their study of the Israeli Defense Force (IDF) concluded that both lower levels of intelligence and poor education contributed to inability to perform in battle (55).

Reuven Gal, Director of the Israeli Institute for Military Studies, presented a paper at the Northeast Regional Conference of the Inter-University Seminar on Armed Forces and Society which identified the differences in fighters and non-fighters. Among the differences revealed was the fact that fighters tended to be more intelligent. Gal also quotes another study that was undertaken on British Bomb disposal operators. Again, the study concluded that intelligence was a prime indicator of performance in a high stress environment (24).

Cohesion/Morale. The third factor which seemed to have a major impact on how individuals performed under the stress of combat situations was the presence of high unit morale.

In writing about the IDF, Belenky described morale as their secret weapon. Since 1948, the IDF has stressed the importance of morale. The IDF even has a scientific appraisal tool to measure the level of morale and unit cohesion. In the spring of 1981, the IDF conducted a survey to determine the factors that contributed to high personal morale (which is a prime contributor to unit morale). A few

of the factors they found that contributed to morale were: (1) confidence in one's own skill, (2) trust in one's weapons, and (3) the unit's cohesiveness (5:15).

Shils and Janowitz wrote extensively on cohesion within the German Army during World War II. They attributed the excellent fighting ability of the Germans to intense cohesion within individual organizations. They further noted that solidarity was fostered by the recollection of jointly experienced ordeals. They concluded that a soldier's ability to resist is directly related to the ability of his organization to avoid social disintegration. Only when social disintegration occurred did the Germans become combat ineffective (54:280-315).

Historical Account of Technical Performance. Perhaps one of the best ways to gain insight into individual technical excellence in combat can be gained by examining past military successes. Captain Alfred Friendly authored The Guys on the Ground, which highlights the exploits and abilities of maintenance technicians during World War II. Captain Friendly travelled extensively during the war and was afforded the opportunity to witness many seemingly technical impossibilities become reality. Several of his accounts clearly demonstrate the technical abilities required to win in combat.

During World War II, the logistical system used to support the Amry Air Corps stretched from one end of the globe to the other. Captain Friendly states that:

> For an enterprise as gigantic, diverse and far-flung as the Air Forces it is beyond human capabilities to operate a perfect supply system, meaning one which provides all the parts for all the planes in all their locations all the time. (22:46)

This lack of capability in the supply system was countered by the ability of maintenance men to scavenge and improvise. The maintainers of the time were pragmatists who learned their ability by working with farm machinery, factory tools, and even their high school "jalopies" (22:10).

Before relating some repair accounts, a brief description of how the Air Corps determined what levels of repair were supposed to have been accomplished by which groups of workers is required. The Air Corps determined that there would be four levels of repair for aircraft. These levels were called echelons. The first echelon of maintenance was to be performed by the flight crews using hand tools. The second echelon was work done with the combat squadron's combined tools. The third echelon consisted of serious repair work requiring power-driven tools too heavy to be carried by aircraft. Finally, the fourth echelon was repair requiring heavy elaborate equipment mounted in place. The technicians of the time did not pay much attention to these arbitrary classifications. In many cases, third and fourth echelon work was performed by men with basic hand tools (22:34).

Examples of third and fourth echelon repairs abound by Captain Friendly's accounts. In one case, a heavily damaged B-24 crash landed after a mission. Damage included

shattered top turret plexiglas, a destroyed belly turret, two destroyed engines, blown brake lines, and severe damage to the left wing tip. The aircraft also had many flak holes in the fuselage. Friendly used the description of damage on this aircraft to demonstrate how many "Joe's" (nameless mechanics) were required to return a heavily damaged aircraft to flyable condition. His list included machinists, armament troops, warehouse men, mechanics, sheet metal workers, and hydraulic technicians. The result of the work by this group of Joe's was an aircraft ready to be flown in five days (22:3-5).

In another instance, a C-47 caught on the ground during a Japanese air raid sustained major damage consisting of over 800 holes in the wings and fuselage. The right wing tip was blown away, a large part of the electrical system was destroyed, and several structural members were badly weakened. Compounding these problems was a complete lack of spare parts or other C-47s from which cannibalization could occur. A new bulkhead and structural members were cannibalized from junked C-56 and B-26 aircraft. After the C-56 and B-26 resources were consumed, steel tubing and two-by-fours were used to complete the structural repairs. The electrical and hydraulic systems were spliced together, and the 800 holes were patched with skin held on by sheet metal screws. The maintenance crew could not come up with a good fix for the damaged wing tip, so they cut off 18 inches and faired the end of the wing. The plane flew without problems

back to an Australian depot over 2,300 miles away (22:11-12).

One of the greatest demonstrations of technical ingenuity occurred when by fate two Flying Fortresses both sustained major damage. One of the Forts nosed-over during take-off resulting in major damage to the forward fuselage. (The engines were also burned beyond repair.) The other Flying Fortress returned from a mission over Germany with over 3,000 holes shot through the aft section of the fuselage. The mechanics came up with the idea to mate the two good halves together to form one good aircraft. Their commanding officer gave the go-ahead as long as the work was completed after hours (The officer felt the idea was too screwy to be put in the workbook.) (22:74-75).

Joining two sections of a heavy bomber together is an extremely delicate task. The job takes on the role of a surgical procedure. The aircraft's structure must be closely aligned, electrical and hydraulic lines must be spliced, and the fuselage must be re-covered with skin where the joint has been made (22:75). The joint must be aligned to a fraction of an inch in order to ensure aircraft stability. The longerons, stringers, and walking beams must all be closely matched and precisely joined together (22:76).

The maintenance unit's ace repairman took on the job of splicing the two planes together as a personal challenge. He began by overseeing construction of jigs to hold the

pieces together. When work commenced on the project, the repairman grabbed idle repair crews to work on the plane at every possible moment. The result was a flyable B-17 nicknamed Odds And Ends (22:74-78).

Individual shops that worked on aircraft were also masters of improvisation. Propeller shops developed knife-edge blades for testing the balance of airscrews, and electric and hydraulic shops developed test stands from parts scavenged from the boneyard (22:39). One electric shop developed a vehicle which served as a mobile repair test stand which could test the entire aircraft electrical system (22:44). In Italy, a sparkplug checker was developed based on a German beer bottle capping machine (22:63).

As important as team efforts were in returning aircraft to flyable condition during the war, individuals often acted as the catalyst to make things happen. In many instances, men brought skills learned in the civilian world with them that proved invaluable in the repair of aircraft or the adaptation of equipment to meet the needs of the moment.

Examples of individual ingenuity abounded during the war. In one case, a mechanic turned bicycle spokes into needles to keep the parachute shop operating (22:41). In another example, a carpenter crafted a wooden propeller for a liaison plane. The wooden propeller worked until a metal replacement propeller was obtained (22:42). In still another instance, a mechanic devised an equipment tester for rubber cord (22:42).

In one unusual case, Tech Sergeant Otie P. Smith devised a method to return four Liberators to flying status and ended up providing needed parts to the entire China-Burma-India Theater. The aircraft in question were grounded for electrical cannon plugs. The insulation in the plugs had deteriorated, and internal arcing was creating electrical problems. Smith was contemplating the problem when a water buffalo walked in front of him. In a flash, Smith seized on the idea of using water buffalo horns to create new plugs. After testing the horns with a hammer and high voltage, Smith machined the horn material to the correct dimensions and installed them on the aircraft. The substitute was deemed better than the original, and orders from the entire Theater flooded in (22:38-39).

Staff Sergeant Victor Havrishko was the technical expert behind the development of a machine shop in the Burmese Jungle. Havrishko's machine shop was at the end of a 10,000-mile supply line. This long replenishment line forced the shop to use every possible scrap they could get their hands on. Havrishko was trained as a machinist in Detroit. He built his shop, dies for various other shops, and a myriad of parts without the help of blueprints. Many dies and parts manufactured by his shop required tolerances down to a fraction of an inch. Havrishko even cast some parts using antiaircraft shells for molds (22:49-51).

Perhaps the ultimate Rube Goldberg was one Sergeant Edward R. Dillon. Before the war, Dillon had been a foundry

molder at Westinghouse Electric. Unhappy with his posting as a truck driver, he set about to do something different. A number of aircraft in India (where Dillon was stationed) were grounded for braces for engine cowling flaps. The parts could not be obtained for several weeks. Hearing about the problem, Dillon felt he could manufacture the required parts. This declaration seemed preposterous at the time because no furnaces, patterns, flasks, molding sand or metal ingots were available. Dillon improvised by using scrap metal, sand, and pancake syrup. The syrup was used as a binder for the sand. Four hours after Dillon had his parts, the first brace was produced. Dillon had found his niche and was assigned to organize and operate a foundry which would supply the entire area with needed forged parts (22:51-55).

Reviewing Captain Friendly's account of World War II maintenance men sheds light on the innovations and ingenuity that were required in order to keep a massive, far-flung Air Corps in the air. Clearly, ingenuity, motivation, and previous experience all contributed to the success of the maintainer.

Summary

This chapter has provided information on expert systems and automated diagnostic equipment. The impact of automation on workers was explored. The psychological impact of automation on workers was discussed, and measures to ensure the successful implementation of automation were

covered. In order to form a link between automation/expert systems and success in combat, literature was reviewed that explained why technicians are affected by combat and how those effects will become manifest on performance. The final section of this chapter provided a historical account of technicians in World War II. Successful technicians of World War II relied heavily on ingenuity and inventiveness in order to keep aircraft flying.

Chapter IV and Chapter V will use the information presented in this chapter to infer what impact automation and expert systems will have on technical traits that have previously proven to be essential to effective combat performance.

IV. Findings

Introduction

This chapter will evaluate the results of the information presented in Chapter III, the Literature Review, to answer the following investigative questions:

1. What effect has automation of skilled jobs had on workers in the civilian community?

2. What technological and psychological traits have led to success in past military conflicts?

3. What types of technological and psychological traits will technicians have who are heavily dependent on diagnostic systems? (For example, to what degree will maintenance technicians be able to improvise when deployed to a combat area?)

4. What lessons can Air Force maintenance managers learn from the civilian community and past military experiences?

Findings of Research

Investigative Question #1: What effect has automation of skilled jobs had on workers in the civilian community?

The effects of automation on the worker are varied and widespread. Some general areas that automation affects are levels of employee job satisfaction, the required degree of job skills needed to accomplish a task, and the characteristics of the job itself.

In general, automation can have opposite effects on the amount of job satisfaction reported by workers. In some cases workers report higher levels of job satisfaction after the introduction of automation, and in other cases workers describe lower levels of job satisfaction. How workers will respond seems to be tied to the characteristics of the job. The connection between the level of employee-reported job satisfaction levels with job characteristics will be addressed later in this section.

Research also indicates that how workers will react to the introduction of new technology, such as automation, varies. It appears that workers will respond to new technology based on the amount of foresight and effort management puts into the introduction of the technological changes. Studies indicate a direct relationship between the amount of effort management expends to help their workers adapt to the new technology being introduced and the level of worker job satisfaction and performance. The more work management puts into human relations, the more likely workers will adapt successfully to automation.

Presently, the only general statement that can be made about the impact of automation on workers is that it is impossible to make broad, general statements. However, one heuristic can be gleaned from research. Workers tend to more successfully adjust to new technology if management develops a plan to help workers overcome the fear of technology-induced changes. This worker adjustment plan

must address any fears employees may have and also ensure that workers are adequately trained to deal with and operate the new equipment.

Research has been more successful in determining what effect automation will have on employees based on job characteristics. For example, studies indicate that the introduction of new technology can have a negative influence on workers who feel they have a very satisfying job. These types of workers feel more threatened by the introduction of automation. These same workers also report higher levels of job dissatisfaction after implementation of new technology.

On the other hand, employees who are in mundane, unskilled jobs report higher levels of job satisfaction after automation is introduced. Studies indicate this increased level of job satisfaction is due to the employee having to acquire more technical ability to operate the new equipment.

The introduction of automation will have huge consequences on organizational culture. Automation has the potential to de-skill jobs and greatly reduce the level of job satisfaction reported by workers. Antithetically, automation can raise the level of job satisfaction employees feel. Research seems to clearly indicate that which employee response is elicited is dependent upon the skill level of the workers before new technology is introduced.

Based on these findings, the worst case scenario would be where a family of jobs requires a high degree of skill

before the implementation of automation and management takes few, if any, measures to help employees ease through the transition. In this situation, it would be reasonable, based on research, to predict a great deal of worker resistance to the new technologically-induced changes. It would also be reasonable to expect that employee job satisfaction levels after the implementation would probably be much lower.

Investigative Question #2: What technological traits have led to success in past military conflicts?

The review of literature did not reveal one predominant trait indicative of superior technological success. Rather, several traits were identified, each of which contributes to the ultimate success of a technological organization. Research concludes that three contributors to technical success are education and training, intelligence, and cohesion/morale of the group in question. Operational accounts reinforce the impact of these traits on success.

Education and training appear to have a greater impact on the individual's ability to perform technological functions than any other factor. Several of the articles reviewed indicated over-learning and in-depth knowledge of a particular area of expertise are critical to success in combat situations. In World War II, for example, men who had previous experience working in foundries or as machinists often were the experts who could manufacture parts from scratch or could literally rebuild aircraft in

remote, inhospitable locations. In one study from the Naval Postgraduate School, education and training were deemed as secondary only to leadership as the human factor most related to combat effectiveness.

Intelligence is another factor which contributes significantly toward success in technological fields. Obviously, individuals must possess some minimum level of intelligence in order to acquire the education and specialized training required to perform technical tasks. However, intelligence also includes the ability to respond quickly and successfully to new situations and to use the faculty of reason in solving problems. Responding to changing situations like those faced in combat and troubleshooting technical problems create a demand for a high level of intelligence. Operational data clearly reflects that individuals in World War II exhibited high levels of adaptability and the ability to reason through extremely complex problems.

A third major factor influencing technological success in past conflicts is the cohesion or morale of the group in question. The Israelis consider morale to be a secret weapon of their elite forces. Many successes of the German Army in World War II were credited not to superior numbers or equipment but to the solidarity of the organizations within the Army. American units in World War II experienced a high degree of unit cohesion. Technical units were often split into individual shops. These shops became entities

with which individuals could identify. The cohesion created by founding different shops resulted in higher levels of performance than would have occurred in generic units.

Expert systems and greater levels of automation will both have an effect on individual training, the need for intelligence, and unit cohesion. Since expert systems are designed to mimic the abilities of the expert within a field, no longer will a high degree of intelligence be required of every technician. Technicians will be expected to rely on the intelligence built into a black box. A reduction in the intelligence required to troubleshoot and repair problems will result in a reduction in training given to individual workers. Since the expert system has in effect been trained, the only training required of the technician will be how to operate the expert system interface and how to accomplish the work the system tells the technician to complete. Finally, units manned with individuals who do not identify with a shop or special group will have a different level of unit cohesion than units whose members have a common core of experiences relating to their particular specialty.

Investigative Question #3: What types of technological and psychological traits will technicians have who are heavily dependent on diagnostic systems? (For example, to what degree will maintenance technicians be able to improvise when deployed to a combat area?)

The degree of technological sophistication possessed by employees dealing with automated diagnostic systems depends on how the automated system is designed and how management keeps in mind the psychological needs of workers. Research notes many examples of organizations carelessly introducing new technology to the work place. Often this new technology reduced the worker to being just a set of hands to do the bidding of the machine. In these situations, the level of technological capabilities of employees suffers greatly.

However, the introduction of automation need not reduce the technological abilities of workers. Also, automation need not stand in the way of satisfying the psychological and social needs of workers. In fact, the skillful design and implementation of automation can make workers more satisfied with their jobs and raise their technological skill levels. Shenandoah Life Insurance Company and Volvo proved this when they used new technology as a catalyst to help workers acquire more and different job skills. In addition, each company reported that workers were more satisfied with their jobs.

Absolutely imperative for management is the need to carefully consider how the introduction of new technology will impact workers. The psychological impacts of new technology are far-reaching and profound. If the psychological needs of employees are not considered, then quite probably the maximum benefit of implementing new technology will not be realized.

Research has many examples of the results of not considering the psychological impact of new technology. In some extreme circumstances, actual cases of sabotage have been reported. Some workers feel pushed to such dramatic measures because they believe their jobs and the chance to progress professionally are threatened by an inanimate machine. Other workers resent having to communicate with a computer in "computerese" and miss the interaction with fellow human beings. Employees may also be apprehensive about having the ability to learn how to operate the new technology, and the use of "computerese" will only exacerbate this problem. Several researchers feel that the root psychological fear workers have when dealing with new technology is the fear of becoming obsolete. Workers who strongly connect their identity to what they do will not only perceive that the job they do is becoming obsolete but that they themselves are slowly becoming antiquated.

If management introduces new technology without consulting, or at least getting the opinion of workers, then employees will feel alienated from management. Often the introduction of new technology leaves the worker with a feeling of helplessness as the workers may perceive they have no control over the new technology. This loss of controllability will greatly reduce the effectiveness of new technology.

On the other hand, research clearly suggests that new technology must be developed with the worker's needs in

mind. If the new technology is designed as a tool for the worker, rather than as a replacement, then the worker will much more readily adapt to new technology and help management realize maximum benefits from systems that are often very expensive. The main objective of management should be to use automation such that workers still have some degree of control over how the task is accomplished. This will give the worker the ability to use his professional skills and the chance to exercise his expert judgments. When the worker is given the opportunity to do this, the person will feel he is an important part of the process in accomplishing the task and not just an impersonal cog in a dispassionate machine.

Investigative Question #4: What lessons can Air Force maintenance managers learn from the civilian community?

Research points to four general areas, or lessons learned, dealing with the influence of automation on the worker. If Air Force leaders pay attention to these lessons learned from the civilian community, the Air Force will be able to avoid many of the pitfalls that have limited the vast potential of automated systems for our civilian analogues. These lessons learned will also allow the Air Force to lessen the impact of new technology on our maintenance technicians.

This section will deal with the four general lessons learned from the civilian community. This section will also include a segment outlining several substantial steps Air

Force managers can take to help in transitioning to the use of new automated diagnostic systems.

<u>Lesson One</u>. It is critical that Air Force managers realize that there is a significant human element to the automation equation. Successful implementation of new technology requires that the person working with the automated system be designed into that system. Therefore, it is critical that the engineers who are designing the automated system keep in mind for whom they are designing the system.

<u>Lesson Two</u>. Air Force maintenance managers must realize that maintenance troops tend to be gregarious people. They spend most of their working day riding around in the same vehicle and work in the same building. Morale often depends on this comradeship. Automation can have a negative influence on morale since automation often reduces the amount of human interaction available to workers. Therefore, new automated systems must be designed to still allow for socialization among maintenance technicians.

<u>Lesson Three</u>. The majority of senior leadership, in the civilian sector have failed to carefully consider the impact of new technology on workers. Coupled with this is the fact that most managers fail to develop even a rudimentary program to help workers deal with technologically-induced changes.

Research indicates several measures Air Force managers can take to help workers adjust to new technology. The most

important step management can take is to develop a thorough, well-thought-out transition plan. This plan should include a section describing how a complete training plan will be implemented. This training plan should ensure that workers will be completely familiarized with the new system they will have to operate. This transition plan should be developed with input from employees, as should the new system itself.

The lack of management's foresight has led to another problem. Research gives examples of companies purchasing very expensive new automation systems without providing an adequate training program. Studies show that management often wants to see an immediate return on investment through increased productivity. However, if workers are not properly trained, and this lack of training is coupled with forcing an unwelcome system onto employees, productivity will drop. This will cause an increase in frustration in both management and workers. Morale will drop and a wedge can quickly develop between management and employees.

Senior leadership must direct the engineers developing the automation system to ensure that workers have at least some degree of controllability over the system. Without this sense of control, workers will feel isolated and frustrated. Employees must have some discretion in planning and controlling the tasks they need to accomplish.

Lesson Four. The fourth general rule gleaned from research is that management must adopt the attitude that new

technology is a tool for workers to use and not a replacement for workers. Research has uncovered considerable evidence demonstrating that the effectiveness of new technology is greatly multiplied if workers feel that the technology helps them achieve higher levels of productivity.

Management can help ensure that automation is perceived as a tool by workers if management considers the social and psychological needs of its employees. Management should also direct computer scientists to design the computer system such that highly specific, technically computer-based languages or directions are not needed to communicate with this system. The use of computer jargon has been shown to greatly contribute to the perception among employees that they are being controlled by the computer instead of the worker controlling the system.

Successful Automation Measures for Managers. There are five steps Air Force managers can take to ensure, as much as possible, that new automation technology can be successfully implemented. The first step is for Air Force leaders to try to reassure maintenance technicians that they will still have a meaningful job after automated diagnostic systems are implemented. With the recent huge cuts in defense spending, military personnel must deal with the possible loss of their livelihood. The introduction of new automated systems will cause the same type of fear of losing a job, in military personnel, as civilian workers experience.

The second step Air Force managers can take is to assess the present organizational culture before the implementation of new technology. This appraisal will serve as a baseline to help Air Force leaders determine the most likely impact of new technology on the maintenance worker. With this knowledge, Air Force officials can develop a sound plan for ensuring the successful transition to the new technology being inaugurated.

Step three consists of establishing a dynamic two-way communication system between Air Force leaders and the personnel who will be working with the new automation systems. Good communication is always needed between management and employees but will be especially needed during the transition period to new technological systems. Without this communication system operating smoothly in both directions, frustrations can develop in both groups. Responsible communication will smooth the transition to new technology, reduce the amount of maintenance worker resistance to change, and help ensure that the maximum benefit can be obtained from the technology being activated.

The fourth step compels the Air Force maintenance leader to recruit the support of the master sergeants who are the first-line supervisors. The attitude of younger employees often closely follows the example set by their section leader. Obtaining the earnest support from older maintenance workers will alleviate many of the problems of introducing new technology.

The last step is probably the most important. This thesis has mentioned several times that an adequate training program is requisite for the successful execution of new technology. Research has emphasized this important function repeatedly. Therefore, the importance of a well-developed and carefully administered training program cannot be overstated.

Summary

This chapter used the information gathered and presented in the Literature Review of Chapter III to answer the following questions:

1. What effect has automation of skilled jobs had on workers in the civilian community?

2. What technological and psychological traits have led to success in past military conflicts?

3. What types of technological and psychological traits will technicians have who are heavily dependent on diagnostic systems? (For example, to what degree will maintenance technicians be able to improvise when deployed to a combat area?)

4. What lessons can Air Force maintenance managers learn from the civilian community and past military experiences?

The findings clearly indicate that the introduction of new technology will have profound consequences on both management and employees. These consequences can be of a positive or negative character. Which outcome is realized

depends in large part on the actions taken by management before, during, and after the implementation of new technology.

The next chapter will give suggestions to Air Force planners as they prepare to design, develop, and realize the implementation of new automated diagnostic systems. The following chapter will also make recommendations about future research studies.

V. Conclusions and Recommendations

Introduction

This chapter will synthesize the information discovered in the literature review to draw conclusions about the possible impact of automated diagnostic systems on maintenance technicians. Recommendations are then proposed that should help ensure that the psychological and social needs of maintenance workers will be met while, at the same time, realizing the maximum benefit of employing new technology.

Conclusions

Morale Impact. The authors of this thesis are extremely concerned about the possible impact the thoughtless introduction of new automated diagnostic systems will have on the morale and unit cohesion of maintenance workers. The literature review and the personal experience of the authors conclusively show that high unit morale and cohesion are essential for successful daily, Temporary DutY (TDY), and wartime operations. As shown in the literature review, new technology can have adverse effects on the morale of workers.

For example, the authors are especially wary about the possible consequences automated diagnostic systems will have on the ability of technicians to troubleshoot. Superior maintenance technicians pride themselves in their abilities

to troubleshoot complex maintenance problems. Many technicians wrap up their professional identities in how well they can track down and isolate stubborn maintenance discrepancies.

However, poorly designed diagnostic systems have the potential to reduce the level of troubleshooting expertise of technicians. If maintenance technicians feel that they have become subservient to the on-board maintenance computer and that they are but a pair of hands to do the bidding of that computer, then it is reasonable to expect serious human-related consequences. These consequences include lower morale and job satisfaction levels and a lessened ability to troubleshoot complex operating systems. Perhaps the most serious consequence would be the stripping away of the professional identities of our best maintenance workers.

Training. The writers of this thesis are also concerned about the direction training will take when diagnostic systems are introduced Air Force-wide. The tremendous abilities of diagnostic systems may tempt some people to save on costs by reducing the amount of training maintenance personnel receive. Lessons from the civilian community and from past military ventures unquestionably show that the reduction of quality training would be a lamentable mistake.

Training of maintenance technicians should be designed to encourage creative thought. Both authors have observed, on numerous TDYs, the importance of ingenuity in maintenance

workers. On more than one occasion, the creativity of maintenance troops has allowed sortie generation to continue in remote locations despite the lack of supply support. An example of creativity was witnessed by one author who saw maintenance troops fabricate special tools to help accomplish difficult tasks.

The authors are also troubled over the possibility that the introduction of diagnostic systems will remove the technician one level from the systems they are assigned to work on. This artificially induced separation can be expected to reduce the interest level and technical abilities of maintenance technicians. To prevent this situation, the automated system should be designed to be a tool for the technician and the technician should be challenged by the training he receives.

Air Force-Sponsored Research. While preparing the literature review for this thesis, the authors were struck by the lack of Air Force-generated research dealing with the human impact of automation. Five in-depth DTIC searches were accomplished in gathering data for this thesis. Many hours were spent in various libraries scrutinizing literally hundreds of research articles. In all of the material examined, we were unable to locate any Air Force sponsored research document dealing with the human aspect of introducing new technology.

On the other hand, there is a plethora of Air Force supported material detailing the technological aspects of

automation. This is disturbing since it seems to suggest that there is a push for technological change with little thought being given to the impact on humans.

The lack of background information on integrating technicians with workers leads us to make several recommendations which should help to create a more holistic approach for the implementation of new technologies within the United States Air Force. The next section outlines these suggested approaches.

Recommendations

Preservation of Morale and Unit Cohesion. Our first recommendation proposes that active measures be taken to ensure that morale and unit cohesion are not adversely affected by the introduction of automated diagnostic systems. One method that can be implemented to help achieve this goal is to guarantee that the people who will be working with the new system will have an active voice in its development. This goal should be easy to accomplish. Computer scientists designing the diagnostic equipment will interview one or more maintenance experts to help develop the decision-making data base used by the expert system. This expert should be used for more than just obtaining maintenance facts and procedures. This maintenance expert should also be questioned about how the workers feel the introduction of the system will affect the average maintenance troop on the flightline. The advice of this expert should be incorporated into the design of the expert

system. These measures will help the engineer design a system that is a valuable complement to the maintenance worker and not a replacement for competent technicians.

As the literature review pointed out, technical expertise is a critical factor in establishing sound unit cohesion and morale. Therefore, we suggest that technical expertise be recognized and encouraged at all levels.

An example of recognition could be in the form of the introduction of a "Master Troubleshooter" patch. This patch would only be awarded to technicians who have demonstrated the highest abilities in troubleshooting complex operating systems. Establishment of such a reward would recognize the pivotal importance of troubleshooting skills. This reward would also encourage technicians to develop skills that are independent from solely operating diagnostic equipment. The authors strongly contend that technicians must have the ability to carry out maintenance actions even if the diagnostic system is inoperable. This ability to continue with maintenance actions without the diagnostic system must be reflected in the training technicians receive. Training will be the subject of the next section.

<u>Complementary Training</u>. Maintenance technicians must receive training both in how to operate the diagnostic equipment, as well as how to conduct maintenance without having the diagnostic equipment operating. Both sets of training should not cancel out the other. Instead, each should reinforce and complement the other. This

complementary training should be conducted in technical school and at the base level.

This two-pronged approach to training should be annotated in the training records (Air Force Form 623) of all maintenance personnel. The 623 should have two separate sections. One section would detail the training needed to become proficient in operating the automated diagnostic system. The second section would contain tasks needed to be accomplished manually without the aid of the maintenance computer. To further stress the importance of this two-pronged training approach, a technician should not be awarded his seven skill level until he has accomplished the training required in both sections of the 623.

Another recommendation is that a policy be implemented that ensures maintenance be carried out periodically on the flightline without the assistance of the diagnostic systems. This training will help our technicians become proficient in conducting manual maintenance.

The authors realize that some may criticize these recommendations since they involve duplication of effort. However, as the military lessons learned in the literature review and the personal experiences of the authors demonstrate, optimum conditions may not always be guaranteed in a TDY or wartime environment. During combat, an intolerable condition would occur if maintenance was unable to generate sorties due solely to the inoperability of the diagnostic system. Maintenance troops must, therefore, have

the knowledge and skill needed to produce sorties despite the many types of adversities encountered. This knowledge and skill can only be acquired by training and conducting maintenance without the service of the diagnostic equipment during peacetime operations.

This dual track training of learning how to operate without the assistance of the maintenance computer should be incorporated into an Air Force-wide strategy on how to deal with the introduction and use of new automated diagnostic systems. This will be the topic of the next section.

Air Force Philosophy. Today the Air Force is undergoing great changes, many of which directly affect the maintenance technician. For example, the Air Force is moving from a three-level to two-level maintenance concept. The number of Air Force Specialty Codes (AFSCs) are being reduced, as are the total number of technicians. Soon, maintenance technicians will have to work on numerous airframes with the introduction of composite wings. These changes will precipitate substantial uncertainties in the maintenance community. If not carefully implemented, the introduction of new technology today will only cause more confusion tomorrow. We recommend that an Air Force-wide comprehensive strategy be developed detailing how new technology will be introduced and employed.

This strategy should include a statement reaffirming the importance of the human maintenance worker. The direction of the Air Force should be to use automated

diagnostic systems as a tool for the maintenance technician and not as a replacement.

This strategy should also map out a carefully managed implementation plan. At first, the new diagnostic system should be activated at only a few test bases. The new technology will then go through a testing period. The purpose of this testing period would be to familiarize maintenance technicians with the system. After the testing period is over, recommendations would be sought from the people who used the system. Only after the system has been thoroughly tested in the field by maintenance technicians, and after recommended changes have been implemented and tested, should the diagnostic system be disseminated Air Force-wide.

This comprehensive Air Force plan must also include a statement accenting the extreme importance of training. Properly designed training was a recurring theme throughout the research papers examined in the literature review. It has been shown that appropriate training will help alleviate the psychological stress felt by workers when introducing new technology. Training will also help ensure that the maximum benefit be realized from the incorporation of expensive automated diagnostic systems. Training is so important that it should be considered an investment, not a cost.

Finally, we recommend that the Air Force actively support much more research into the human aspect of

introducing new technology. This research is vital if a sound Air Force strategy is to be developed. Additional research is also essential in order to ensure that automated diagnostic systems and the technical abilities of maintenance technicians combine in a synergistic manner. Recommendations for possible avenues of research will be made in the next section.

Research Recommendations

Because the Air Force has invested little in investigating the impact of automation on humans, there is much work to be done in this area. This section will make recommendations for possible research topics for future analysis.

The civilian community has a considerable amount of experience in developing and implementing automation. The Air Force can tap this experience and gain great dividends by examining what the civilian community has done to make automation a success. Specifically, a review should be undertaken to examine the steps civilian senior management took to help ensure successful deployment of automation.

The use of surveys would be quite useful in expanding the Air Force's knowledge of how automation impacts its maintenance technicians. For example, a survey could be directed toward senior noncommissioned officers and maintenance officers who supervise troops working on aircraft with automated diagnostic systems. This survey should be designed to obtain their opinions of how the

implementation of automated diagnostics has affected their workers. Particular attention should be paid to determining the impact automation has had on unit cohesion, morale, levels of job satisfaction, and technical abilities. A survey should also be accomplished that would ask maintenance technicians about features they would like to see incorporated into automated diagnostic equipment. A final survey could be focused on determining the organizational culture of a unit before implementation of new automated equipment. Maintenance managers should then use this survey as a baseline to help determine the likely impact of new technology on the maintenance worker and the maintenance organization.

A great deal of knowledge into the effects of automation could be obtained by doing a comparative study. This study would be directed at units working with and without aircraft diagnostic equipment. Comparisons could then be drawn about the technological capabilities of technicians who work with expert systems to those who conduct maintenance in the more traditional manner. Part of this comparison could consist of comparing the Specialty Knowledge Test (SKT) scores of both groups of technicians. SKT scores could then be analyzed to determine if there is a statistical difference between the group that uses the automated equipment to the group that does not.

The authors recommend that the U.S. Air Force follow the lead of the Israeli Defense Forces who have committed a

great deal of resources to determining personality traits that make for a successful soldier or airman in a combat situation. The U.S. Air Force must identify traits requiring cultivation in its troops. Then, a series of studies should be undertaken to determine if present and future designs of automated diagnostic equipment strengthen or inhibit the development of these combat characteristics.

Finally, we recommend that computer scientists start work on developing computer interface languages that are friendly for use by the average Air Force maintenance technician. Both authors have observed first hand the agitation caused by maintenance technicians having to interface with computers in "computerese." A friendly and skillfully designed human/computer interface will do much to relieve the psychological stress of introducing new technology to maintenance workers.

Conclusion

This thesis has addressed the possible implications of implementing new automated diagnostic systems into aircraft in the Air Force environment. Specifically, this thesis has concentrated on the human portion of the equation of introducing new technology.

This study has projected the possible influence of diagnostic systems on the maintenance technician by reviewing three major bodies of information. The first area was devoted to describing what expert systems are and how they relate to diagnostic systems. Included in this section

was an explanation of the possible technical benefits of using diagnostic equipment for aircraft maintenance. The second major body of information reviewed the effects of automation on civilian workers. The last area outlined several traits that have been critical for success in combat situations. The information discovered in these three areas was then synthesized and used to draw conclusions and make recommendations.

Based on the results of this research, it is strongly recommended that the Air Force carefully consider how automated diagnostic equipment is to be implemented and employed. Specific attention should be given to maintaining unit cohesion and morale, and developing a comprehensive training program.

The enlisted maintenance troop has been, and will continue to be, the backbone, muscle, and sinew of the Air Force. In this era of tremendous change, we as Air Force leaders and managers, must take aggressive active measures to do everything we can to help these superb people do their jobs with as little outside disruption as possible. Introducing new technology is one possible area of disruption. This thesis has begun the task of mapping out where automation may lead us and how best to integrate automation into our organizations. Until this area has been researched fully, we cannot hope to realize the ultimate effects of automated diagnostic equipment on technicians.

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